EML 3100 Exam 4 **THERMODYNAMICS** **4/23/08 3:00-5:00 pm**
Page 1/4 Solutions (dommelen@eng.fsu.edu) series a

DO NOT WRITE ON THE BLUE TABLES. RETURN THE BLUE TABLES WITH YOUR EXAM. DO NOT STAPLE THE EXAM SHEETS TOGETHER. Put your answers on the same sheet as the question, Use many digits in your computation. You must give the units of your answers. You must write clearly. Encircle the right answer number in multiple choice. To correct, erase the wrong circle as well as you can and encircle the corrected answer number twice. Best possible answer for multiple choice. For questions asking a number, putting the clear correct formula(s) below the question might result in partial credit even if the answer is wrong. *Not following those requirements will result in reduced or no credit.*

1. (3%) Which of the following items is best described as a control mass, normally speaking.
   - (a) A running faucet.
   - [✓ (b)] A wall.
   - (c) A shopping bag being emptied.

2. (3%) An isentropic pressure increase
   - (a) can turn a liquid-vapor mixture into all liquid.
   - (b) can turn a liquid-vapor mixture into all vapor.
   - [✓ (c)] both of the above.

3. (3%) The enthalpy of argon is increasing at a rate of 3 kJ/kg-s. Its temperature is changing at a rate of 5.77 °C/s.

4. (3%) Liquid water enters a pump at 25°C and 100 kPa and exits it at the same velocity and height as it entered, pressurized to 1 MPa. Assuming the pump is reversible, its work requirement is about 0.902 kJ/kg.

5. (3%) Two kg of watery soup, heated to boiling, is put on a table. Since no one wants watery soup, it ends up cooling down to the 20°C room temperature. The entropy generated by this process is 0.2644 kJ/K.

6. (3%) If 2 kg/s of air at 100 kPa and 27°C is flowing through a pipe with a diameter of 20 cm, the flow velocity in the pipe will be 54.81 m/s.

7. (3%) In these days of higher energy costs, it is good to remember that a resistance heater using 1 kW of electricity can only add 1 kW of heat to your house. If it is -5°C outside and 15°C inside, an ideal heat pump could add as much as 14.4 kW of heat to your house for that same 1 kW of electricity.

8. (3%) Water at 100 kPa has an entropy of 1 kJ/kg-K. The water is

   [✓ (a)] compressed liquid.
   (b) saturated.
   (c) superheated vapor.

9. (3%) An accurate thermometer put into a pot of boiling water reads 65°C. The ambient pressure is, to 3 digits accuracy, 25 kPa.

10. (3%) If 100 kW of heat is produced by the fuel burned in your engine and 70 kW of heat is lost to the surroundings, the thermal efficiency of your engine is 0.3 .

11. (35%)

    (a) An adiabatic, but not reversible, compressor takes in helium at 100 kPa and 27°C and compresses it to 500 kPa and 327°C. Kinetic and potential energy can be ignored. What is the specific work w required for the compressor?

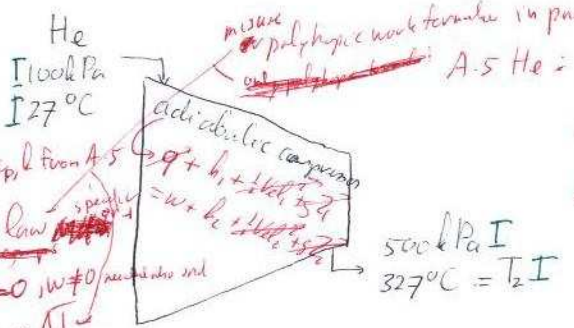
    (b) Now consider the *reversible* adiabatic version of the same compressor, with the same entrance conditions and the same exit pressure. What is the exit temperature $T_{2,s}$ for that compressor? So what is its specific work requirement w_s?

    (c) Define the isentropic compressor efficiency of the compressor of question (a) in words and state its value.

    (d) If the compressor in (a) operates in an environment that is at 20°C, what is the entropy generated by irreversible processes? What is it for the compressor in (b)?

You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.

a)



$q + h_1 + \cancel{\tfrac12 V_1^2} + gz_1 = w + h_2 + \cancel{\tfrac12 V_2^2} + gz_2$

misuse polytropic work formula in part b → -2 in 1st law

~~only polytropic~~

A-5 He: $R = 2.0771 \frac{kJ}{kg\,K}$

$c_p = 5.193 \frac{kJ}{kg\,K}$

$k = 1.667$

③ R, c_p, k from A-5

⑤ 1st law ~~[illegible]~~ specific

④ $q = 0$, $w \neq 0$ / needed also 2nd

④ $\Delta h = c_p \Delta T$ + comps

⑤ $s_2 = s_1$ needed also 2nd

~~polytropic~~

Asked: w

1st law: $w = h_1 - h_2 = c_p(T_1 - T_2) = -5.193 \frac{kJ}{kg\,K}\, 300\,\mathrm{K}$

$= -1557.9 \frac{kJ}{kg}$

b) ~~$T_2 = 327$~~ reversible + adiabatic = isentropic + constant heats } polytropic $n = k$

④ compute T_2 Δs(c.-1)

③ η_{comp} def + value

$$\left(\frac{T_2}{T_1}\right) = \left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = 1.904 \rightarrow T_2 = 1.904\ 300\,\mathrm{K} = 571.206\,\mathrm{K}$$

$= 298\,°\mathrm{C}$

~~2nd law~~

$w = -5.193 \frac{kJ}{kg\,K}(571.206 - 300)\,\mathrm{K} = -1408.4\ \mathrm{kJ/kg}$

~~④ s_gen~~

c) $\eta_{comp} = \dfrac{\text{work needed for ideal compressor with same } P_2}{\text{actual work}}$

~~comps~~

$= \dfrac{-1408.4}{-1557.9} = 0.904$

④ $s_2 - s_1 = \cdots$ + comps

③ incorrectly includes T_{surr} or same q

q≠0, $s_2 = s_1$ in cooling terms

d) $s_{gen} = s_2 - s_1 - \cancel{\dfrac{q}{T_{surr}}}$ → q = 0 adiabatic

$= c_p \ln T_2/T_1 - R \ln \dfrac{P_2}{P_1} = \left(5.193 \ln \dfrac{600}{300} - 2.0771 \ln 5\right)\dfrac{kJ}{kg\,K}$

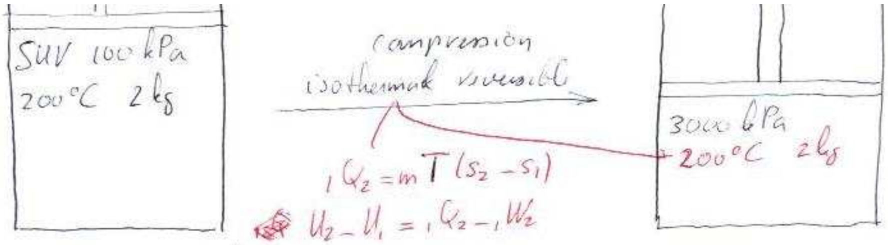
$= 0.2565\ \mathrm{kJ/kg\,K}$. For (b), of course 0

12. (35%) Two kg of superheated steam initially at 100 kPa and 200°C is isothermally and reversibly compressed to 3000 kPa. What are the heat and work associated with this process?

    You must construct all phases that are not given in the Ts-diagram, marking all lines and points used to do it with their values. Unambiguously number the phases in the diagram.

    Also show the process as a fat curve in the diagram.

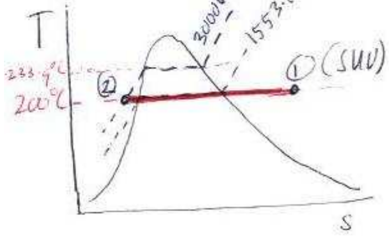
    You must show the derivations and reasoning completely and correctly for full credit. You must give units for your answers. Most accurate procedure only unless stated otherwise.



$_1Q_2 = mT(s_2 - s_1)$

$U_2 - U_1 = {}_1Q_2 - {}_1W_2$

Asked: $_1Q_2$, $_1W_2$, phase 2



① Table B1.3 @ 100 kPa, 200°C

$u_1 = 2658.05$ kJ/kg $s_1 = 7.8342$ kJ/kg-K

② Table B.1.4 @ 3000 kPa, 200°C

interpolated

$$u_2 = \left[850.36 + \frac{3000-2000}{5000-2000}(848.08 - 850.30)\right]\frac{\text{kJ}}{\text{kg}}$$

$$s_2 = \left[2.3301 + \frac{3000-2000}{5000-2000}(2.3254 - 2.3301)\right]\frac{\text{kJ}}{\text{kg K}}$$

$u_2 = 849.56\ \frac{\text{kJ}}{\text{kg}}$ $s_2 = 2.32853\ \frac{\text{kJ}}{\text{kg K}}$

$$_1Q_2 = mT(s_2 - s_1) = 2\,\text{kg}\,(200 + 273)\,\text{K}\,(2.32853 - 7.8342)\frac{\text{kJ}}{\text{kg K}}$$

$$= \underline{-5208.36}\ \underline{\text{kJ}}$$

$m(u_2 - u_1) = {}_1Q_2 - {}_1W_2$ $2\,\text{kg}\,(849.56 - 2658.05)\frac{\text{kJ}}{\text{kg}} = -5208.36\,\text{kJ} - {}_1W_2$

$_1W_2 = \underline{-1591.38}\ \underline{\text{kJ}}$

○ diagram
○ line 1
○ sat table
○ plot sat

~~○ Table B1.3~~
~~○ heat formula~~
○ Table B1.4
○ interpolated
○ heat formula

① diagram
① line 1
① sat value 2
① plot
① line 2
① IP
① process line
⑤ $T_2 = T_1$

③ read B.1.3
③ read B.1.4
ignore interpolate ← difference is too small to notice
⑦ heat formula and comp specific
⑦ 1st law ($m_2 = m_1$) and comp specific
units:
②
① $m_2 = m_1$